**Experiment**

**5**

Archimedes Principle

# Introduction

There is a story that is told about Archimedes (287-212b.c.) that occurred when he was commissioned by King Hiero II to determine whether the royal crown was made of pure gold. The king did not trust the goldsmith, and he worried that some silver (alloyed with gold) may have been used rather than the pure gold the King paid for. This request of Archimedes was difficult at the time because the only known way to take a piece of the crown material and chemically test it. This was strictly forbidden, so the problem Archimedes faced was how to determine the crown’s composition without altering it in any way. As the story goes (according to Syracuse), one day Archimedes was seen running naked down a street in central Athens screaming “Eureka! Eureka!” (L: “I’ve found it!). What he had found was a way to solve the crown problem, and this was not just coincidence. What followed were Archimedes’ famous principle and the death of the dishonest goldsmith. In this experiment, you will find out how to measure the density of irregularly shaped objects and more using this principle.

**Apparatus**

Zero

Adjustment

0 Zero

Floater

Sinker

Figure 1 Figure 2 Figure3

# Procedure

1. Carefully zero the balance.
2. Attach one of the metal cubes to the bottom loop 2 - of string, bring to balance and record its mass in Table 1.
3. Add some tap water to the beaker and carefully place the suspended metal cube inside (See Figure 1). This initial water is to protect the beaker in case the sample detaches from the string.
4. Add more water to the beaker to bring its level just above the cube as shown in figure 1.
5. Balance and record the buoyant mass of the sample in Table 1.
6. Repeat steps 1 through 4 for the other known material, the unknown one, and the bolt. Be sure to clean up any water spills. Place wet objects on a paper towel to dry.
7. Attach the floating block to the upper loop of string and the one of the metal cubes to the bottom of the floating block, and carefully lower the blocks into the beaker as instructed in step 3.
8. Now add water and fill the beaker to the level shown in figure 2, balance and record this mass as “reading #1” in Table 1.
9. Add more water until the level is as shown in figure 3, balance and record this mass as “reading #2” in Table 1.
10. Measure and record the mass of the floating block (in air) in the space below Table 1.
11. Determine the volume of the block by measuring its dimensions. Make sure you measure each dimension at five locations to determine the average and uncertainty of each dimension. The values from Steps 10 and 11 will be used to determine the reference density of the floating block.
12. Finally, repeat 3, 4, and 5 using a saturated aqueous solution in place of the water. Be particularly careful with the saturated aqueous solution. Save the saturated aqueous solution in its original container and rinse everything completely with water to remove the salt residue.

## Theory

1. In the space below, state Archimedes’ Principle, then show mathematically how you can measure the density of an object using this principle. Be sure to draw a free-body diagram of the mass attached to the string. What does the tension in the string measure?

T

# Archimedes Principle

Here we find the system in equilibrium if Force acting upward is equal to the force acting downward.

The force acting upward is equal to density times gravity times the volume of the object.

Force two is equal to the mass of the object times the gravity of the system.

Therefore, we find buoyant force to equal mass times gravity

– M\*g

Here we find the system is in equilibrium.

The string measures the active buoyant force which is equal to the weight.

M

1. Derive an equation for determining the density of a floating object using Archimedes’ Principal.

**Using the equation**

**We move mg to the opposite side**

**Then divide by**

**We find**

1. Finally, derive an equation using Archimedes’ Principal showing how the density of a liquid can be measured. Your expression should be in terms of the density of water, object’s mass in water, the object’s mass in a saturated aqueous solution, and the object’s mass in air *(i.e.* in terms of the quantities in Table 1). No free-body diagram is needed.
2. An object of volume V is placed in water. The amount of water that is displaced is 75% of the object’s volume. Derive the value of density of the object. Show all work.

## Data

Use 1.00g/cm3 (3 significant figures) for the density of water.

#### Table 1: Density Measurements

|  |  |  |  |
| --- | --- | --- | --- |
| Substance | Mass (g) | Buoyant Mass (g) | Change in Mass (g) |
| Material 1 |  |  |  |
| Material 2 |  |  |  |
| Unknown 1 |  |  |  |
| Unknown 2 |  |  |  |
| Floating object | Reading #1 | Reading #2 |  |
| Saturated Aqueous Solution |  |  |  |

### Mass of floating block in air before: \_\_\_\_\_\_±\_\_\_\_\_

**Dimensions of floating block with uncertainty:**

**L1=\_\_\_\_\_\_\_\_\_\_; W1=\_\_\_\_\_\_\_\_\_\_; H1=\_\_\_\_\_\_\_\_\_\_;**

**L2=\_\_\_\_\_\_\_\_\_\_; W2=\_\_\_\_\_\_\_\_\_\_; H2=\_\_\_\_\_\_\_\_\_\_;**

**L3=\_\_\_\_\_\_\_\_\_\_; W3=\_\_\_\_\_\_\_\_\_\_; H3=\_\_\_\_\_\_\_\_\_\_;**

**L4=\_\_\_\_\_\_\_\_\_\_; W4=\_\_\_\_\_\_\_\_\_\_; H4=\_\_\_\_\_\_\_\_\_\_;**

**L5=\_\_\_\_\_\_\_\_\_\_; W5=\_\_\_\_\_\_\_\_\_\_; H5=\_\_\_\_\_\_\_\_\_\_;**

**LAVG±δL=\_\_\_\_\_\_\_\_\_\_\_; WAVG±δW =\_\_\_\_\_\_\_\_\_\_; HAVG±δH =\_\_\_\_\_\_\_\_\_\_**

**Volume of the floating block and its uncertainty (show work): \_\_\_\_\_\_\_\_\_\_\_**

## Analysis

1. A. Show in detail in the space below the calculation of the density of Material 1 using your derived equation.

B. Propagate the error to determine the uncertainty in your value.

1. In a similar manner, calculate the density of the object that floats and its uncertainty.
2. Finally, calculate the density of the liquid and its uncertainty.
3. Calculate the reference density of the floating block and its uncertainty.

### Results:

**Table 2: Measured Densities**

|  |  |  |  |
| --- | --- | --- | --- |
| Substance | Measured Density | \*Reference Density | % Error |
| Material 1 | ± |  |  |
| Material 2 | ± |  |  |
| Unknown | ± |  |  |
| Unknown | ± |  |  |
| Floater | ± | ± |  |
| Saturated Aqueous Solution | ± |  |  |

\*Using the handbook (or other similar references) look up and record the densities of as many of these materials as you can find.

1. Do your measured values agree with the reference densities?
2. Determine the elements from which the bolt and unknown are made.
3. List your references.

# Questions

1. Solid cubic blocks A and B both have a weight of 10 pounds. When they are placed in water, block A floats, and block B sinks.
2. Which block is smaller? A B C(same)
3. Which block is denser? A B C(same)
4. Which block is lighter? A B C(same)
5. Larger buoyancy force is on A B C(same)
6. If both blocks mentioned above are totally immersed in water, the larger buoyancy force will be on A B C (same)
7. Solid cubic blocks A and B both have a volume of 10 ft3. When they are placed in water, block A floats, and block B sinks.
   1. Which block is denser? A B C(same)
   2. The smaller buoyancy force is on block A B C(same)
   3. If both blocks are totally immersed, the larger buoyancy force would be on

A B C(same)